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Anxiety-induced changes in movement behaviour during the execution of a complex whole-body task

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We investigated the impact of anxiety on movement behaviour during the execution of a complex perceptual-motor task. Masters' (1992) conscious processing hypothesis suggests that under pressure an inward focus of attention occurs, resulting in more conscious control of the movement execution of well-learned skills. The conscious processes interfere with automatic task execution hereby inducing performance decrements. Recent empirical support for the hypothesis has focused on the effects of pressure on end performance. It has not been tested so far whether the changes in performance are also accompanied by changes in movement execution that would be expected following Masters' hypothesis. In the current study we tested the effects of anxiety on climbing movements on a climbing wall. Two identical traverses at different heights on a climbing wall provided different anxiety conditions. In line with the conscious processing hypothesis we found that anxiety had a significant effect on participants' movement behaviour evidenced by increases in climbing time and the number of explorative movements (Experiments 1 and 2) and by longer grasping of the holds and slower movements (Experiment 2). These results provide additional support for the conscious processing hypothesis and insight into the relation between anxiety, performance, and movement behaviour.

When the pressure is high, performance becomes less predictable. In sports, for example, some top athletes thrive under the pressure while others miserably fail, especially at these crucial moments of, for instance, a decisive penalty shot in soccer or a match point in tennis. What does it mean to execute perceptual-motor skills under high pressure? Why do some seem to benefit from stressful situations while others seem to suffer under those circumstances? In what way are movements different when they are executed in anxiety-provoking situations compared to more neutral situations? To answer the question why anxiety may

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influence expert performance it does not suffice to just explore the effects of anxiety on one's global performance (the "end result of a motor act", Weinberg & Hunt, 1976). Instead, also the mechanisms affecting the performance should be considered, such as changes in the execution of movements (e.g., Beuter & Duda, 1985; Collins, Jones, Fairweather, Doolan, & Priestley, 2001; Janelle, 2002; Martens, 1971; Mullen & Hardy, 2000; Schmidt, 1982; van Loon, Masters, Ring, & McIntyre, 2001; Weinberg, 1978). The (pioneering) work of Weinberg (1978; Weinberg & Hunt, 1976) and Beuter and Duda (1985; Beuter, Duda, & Widule, 1989) illustrated the importance of examining anxiety and accompanying changes in movement pattern. These authors demonstrated differences in co-ordination patterns suggesting less efficient movements in high-anxiety conditions. Obviously, insight into the relation between anxiety and movement behaviour may have implications for designing techniques to control anxiety in order to optimize performance on perceptual-motor skills in several domains such as sports (e.g., Gould & Udry, 1994), dance (e.g., Wilson, 2002), making music (e.g., Stanton, 1994), police work (e.g., Anderson, Litzenberger, & Plecas, 2002; Le Scanff & Taugis, 2002), work of fire fighters (e.g., Ryan, Ployhart, Greguras, & Schmit, 1998), and armed forces (e.g., Arthur, Young, Jordan, & Shebilske, 1996).

Before we turn to the relation between anxiety and movement behaviour, we will define "arousal", "anxiety", and "stress", terms that are surrounded by considerable confusion in the literature (e.g., Janelle, 2002; Landers & Arent, 2001; Landers & Boutcher, 1998; Woodman & Hardy, 2001). Landers and Arent recommend not using these terms interchangeably and conceptually distinguishing the terms as follows. Arousal refers to "... a nondirective generalized bodily activation . . . and is thought to range from a comatose state to a state of extreme excitement as might be manifested in a panic attack" (Landers & Arent, 2001, p. 129). In contrast to arousal, which is nondirective, having either beneficial or detrimental effects on performance (e.g., Wann, 1997), anxiety is seen as directional in that it is an unpleasant emotional state (e.g., Woodman & Hardy, 2001). In other words, "anxiety is by definition a negative feeling state" (Jones & Hanton, 2001, p. 393). Anxiety occurs as a result of threat (Schwenkmezger & Steffgen, 1989), and this threat is "related to the subjective evaluation of a situation, and concerns jeopardy to one's self-esteem during performance or social situations, physical danger, or insecurity and uncertainty" (Schwenkmezger & Steffgen, 1989, pp. 78–79). Thus, anxiety has a mental element (e.g., worry, apprehension), which is called cognitive anxiety, and a physiological element that matches the construct of arousal as defined above and is called somatic anxiety (Martens, Vealey, & Burton, 1990) or physiological arousal (Woodman & Hardy, 2001). Finally, stress is seen as a result of demands placed on the individual that are perceived to exceed available coping abilities (e.g., Janelle, 2002; Selye, 1976). Depending on one's interpretation of the environmental demands stress will be conceived as positive, negative, or neutral. The negative form of stress is called distress or anxiety and can have detrimental effects on performance (Wann, 1997).

In the present study we focus on the impact of anxiety on *movement* behaviour to gain further insight into the anxiety–performance relationship and to explore the mechanisms underlying this relationship. To explain the (debilitative) effects of anxiety and the relation between anxiety and movement behaviour, research has resorted to the underlying attentional mechanisms: Influences of state anxiety on performance are assumed to be related to changes in attention and concentration (Janelle, 2002; Landers, 1980; Nideffer, 1976, 1981).

Consequently, in the course of time, several attentional models have been put forward in the literature. The models are based on the assumption that for successful performance one should attend to task-relevant information while ignoring task-irrelevant information (Lewis & Linder, 1997). Broadly, the models can be classified in either distraction models or self-focus models (see Beilock & Carr, 2001; Lewis & Linder, 1997; Mullen & Hardy, 2000).

Distraction models propose that some stimuli (e.g., anxiety) shift attention away from task-relevant information to distracting, task-irrelevant cues (either externally or internally), thereby decreasing performance (see Beilock & Carr, 2001; Lewis & Linder, 1997; Mullen & Hardy, 2000). For example, Wine's (1971) distraction model draws upon a difference in attentional focus of high- and low-(test-)anxious persons during task performance to explain (debilitating) effects of anxiety on performance. Highly test-anxious persons often divide their attention between task-irrelevant (i.e., self-evaluative worry) and task-relevant variables whereas low-test-anxious persons focus their attention more fully on the task.

The self-focus models state that pressure and anxiety raise self-consciousness and evoke an inward focus of attention (Baumeister, 1984; Masters, 1992). The increased inward attention might induce a conscious step-by-step control of movement execution disrupting the normal, automatic processing of the task at hand and leading to a decrease in performance (Baumeister, 1984; Beilock & Carr, 2001; Lewis & Linder, 1997). Masters (1992) called this the "conscious processing hypothesis" (see also Masters, 2000; Masters, Polman, & Hammond, 1993). The proposed anxiety-induced renewed conscious control may reflect a temporary regress to a lower skill level or an earlier stage of learning (Baumeister, 1984; Beilock, Carr, MacMahon, & Starkes, 2002a; Beilock, Wierenga, & Carr, 2002b; Masters, 1992, 2000; Mullen & Hardy, 2000; Pijpers, Oudejans, Holsheimer, & Bakker, 2003). Such a regress implies more cognitive control of movements, as is also found in earlier stages of learning (Fitts & Posner, 1967). This is supposed to be detrimental to skilled performance as it interferes with the well-learned automatisms of the skill.

In the present study, we mainly draw upon Masters' (1992) conscious processing hypothesis as it holds some promise with respect to explaining influences of anxiety on *movement* behaviour.¹ In the last decade, several research groups have provided empirical support for the conscious processing hypothesis, especially with respect to golf putting (Beilock & Carr, 2001; Beilock et al., 2002a; Beilock et al., 2002b; Hardy, Mullen, & Jones, 1996; Lewis & Linder, 1997; Masters, 1992; Mullen & Hardy, 2000), but also the more continuous task of soccer dribbling (Beilock et al., 2002a). However, so far these studies concerned the testing of the relationship between pressure and performance (Beilock & Carr, 2001; Hardy et al., 1996; Lewis & Linder, 1997; Masters, 1992; Mullen & Hardy, 2000) as well as between the proposed attentional mechanisms and performance (as end product; Beilock et al., 2002a). Research into the relation between anxiety and movement behaviour is scarce.

Following the conscious processing hypothesis it is assumed that under the influence of anxiety movement behaviour will have characteristics that are typically found in early stages of motor learning. Movements in early learning are uncertain, confused, and clumsy

¹In this regard, the "processing efficiency theory" (Eysenck & Calvo, 1992), popular in recent sport scientific literature (e.g., Hardy & Jackson, 1996; Janelle, 2002; Mullen & Hardy, 2000; Smith, Bellamy, Collins, & Newell, 2001; Woodman & Hardy, 2001), seems less suitable as its main emphasis is on the relation between anxiety and performance outcome, rather than movement behaviour.

(Bernstein, 1996). More specifically, learning a skill is accompanied by irregular, jerky, less fluent, and slow movements requiring much effort (Beilock & Carr, 2001; Beilock et al., 2002a; den Brinker, Stäbler, Whiting, & van Wieringen, 1986; den Brinker & van Hekken, 1982; Magill, 1998; Masters, 1992; Vereijken, van Emmerik, Whiting, & Newell, 1992; Vincken & Denier van der Gon, 1985; Whiting, Bijlard, & den Brinker, 1987). In addition, movements in early learning are found to be restricted in amplitude (den Brinker et al., 1986; Vereijken, Whiting, & Beek, 1992).

Beuter and Duda (1985), Collins et al. (2001), and Weinberg and Hunt (1976) provided evidence that under the influence of anxiety performance was characterized by less fluent movements. In a previous study we investigated the effects of anxiety on movement behaviour of participants executing a complex whole-body task, namely, climbing a traverse on an artificial climbing wall (Pijpers et al., 2003). By building traverses at different heights on the wall anxiety was manipulated in an ecologically valid situation that was both safe and frightening (Baddeley, 1972; Idzikowski & Baddeley, 1987). We could hereby examine anxiety effects “in-event” (Collins et al., 2001), while applying an intraindividual design to enhance power to identify changes in the dependent variable of interest (i.e., movement performance) (Jones, 1995). We found that high on a climbing wall (i.e., under high-anxiety conditions), participants climbed less efficiently than low on the wall (Pijpers et al., 2003). In addition, we found longer climbing times and a less fluent displacement of the body’s centre of gravity when participants were anxious, as would be expected on the basis of the conscious processing hypothesis.

Although longer climbing times were expected, the results of our study (Pijpers et al., 2003) remained mute as to why participants’ climbing times increased so much (by almost 50%) and about what exactly happened with participants’ limb movements underlying the decrease in fluency of the displacement of the body’s centre of gravity. For instance, did participants make more limb movements? Did they grasp the holds longer? Did they move slower from hold to hold? In the present study we investigated these questions with two experiments to further test Masters’ (1992) conscious processing hypothesis and gain more insight into the anxiety–performance relationship by focusing on changes in movement execution.

EXPERIMENT 1

The purpose of Experiment 1 was to examine anxiety-induced changes in movement behaviour. We asked participants to perform a climbing task low (low-anxiety condition) and high (high-anxiety condition) on a climbing wall. No time constraints were imposed. Following the conscious processing hypothesis (Masters, 1992) we expected that participants would make more movements under anxiety conditions. Gibson (1988) distinguished “exploratory actions” and “performatory actions”, where exploratory actions are primarily information-gathering actions (e.g., when a climber just wants to find out whether he or she can reach a particular hold). Performatory actions are executive actions meant to reach a certain goal (e.g., moving a hand from one hold to the next in order to use it as support).

Because in early learning movements are more uncertain, and the learner executes more exploratory movements (e.g., Gibson, 1988; Gibson & Spelke, 1983; Newell & McDonald, 1992; Von Hofsten, 1990), we also expected more exploratory movements when climbing

high than when climbing low on the wall. In addition, as we expected that movements would have smaller amplitudes under anxiety conditions, we expected that participants would use more holds—that is, make more performatory movements—when climbing high on the wall than when climbing low on the wall. Therefore, compared to the traverse we used in our earlier study (Pijpers et al., 2003), we now added two extra holds that were not strictly necessary to perform the climbing task. Together, the expected anxiety-related changes in the number of exploratory and performatory movements would at least partly explain the longer climbing times that were found by Pijpers et al.

Method

Participants

A total of 8 male participants, mean age 31.4 years ($SD = 4.81$) volunteered to participate in the experiment. The participants had no experience in climbing and were naive to the purposes of the experiment.

The Dutch version of the A-Trait scale of the State-Trait Anxiety Inventory (STAI)² was used as a standard check to measure trait anxiety (Spielberger, Gorsuch, & Lushene, 1970; van der Ploeg, Defares, & Spielberger, 1979). The mean trait anxiety score for the participants was 31.9 ($SD = 6.24$) and was not significantly different from the mean score for Dutch male college students ($M = 36.1$) obtained by van der Ploeg, Defares, and Spielberger (1980), $t(7) = 1.90$, *ns*, *t* test between a sample and a population mean (Thomas & Nelson, 1996). The results indicate that the participants had no extraordinary tendency to respond to situations perceived as threatening with an elevation in state anxiety (e.g., Smith, Smoll, & Wiechman, 1998).

Materials

Participants climbed on a vertical climbing wall (width 3.5 m; height 7.0 m; see Figure 1), which was placed in a gym-sized laboratory. The wall had a grey grainy texture for friction. Holds of varying shape and size could be bolted on the wall at relative distances of about 0.15 m.

On the wall, two identical, horizontal routes (so-called “traverses”, built by a professional route designer) were mounted (see Figure 1). Each traverse consisted of six footholds and seven handholds of varying size and shape, which were all suitable for novice climbers. Holds 12 and 13 (see Figure 1) were labelled “additional holds” because these holds were not necessary to climb the traverse successfully as was shown in a previous study (Pijpers et al., 2003). The mean height of the footholds of the low traverse was 0.4 m (*low* condition); the mean height of the footholds of the high traverse was 5.0 m (*high* condition). To be able to start with the high traverse in the same physical condition as in the low traverse, a movable platform, 5.0 m above the floor, was placed 1.2 m in front of the climbing wall.

The participants wore well-fitting climbing shoes (Enduro 954, La Sportiva). In both conditions participants wore an integral harness (Edelrid). We used the so-called “top-roping” technique to ensure the safety of the participants. Top-roping involves “paired” climbing (Skinner & McMullen, 1993)—that is, one end of the rope is tied onto the participant’s harness, and the safety rope runs up

²The STAI A-Trait scale is a self-report questionnaire that measures anxiety proneness—that is, the tendency to respond to situations perceived as thrilling with an elevation in state anxiety intensity. Scores range from a low of 20 to a high of 60. Normative data for the STAI A-Trait scale depict a mean score of 36.1 ($SD = 8.4$) for male college students and of 37.7 ($SD = 8.4$) for female college students (van der Ploeg, Defares, & Spielberger, 1979).

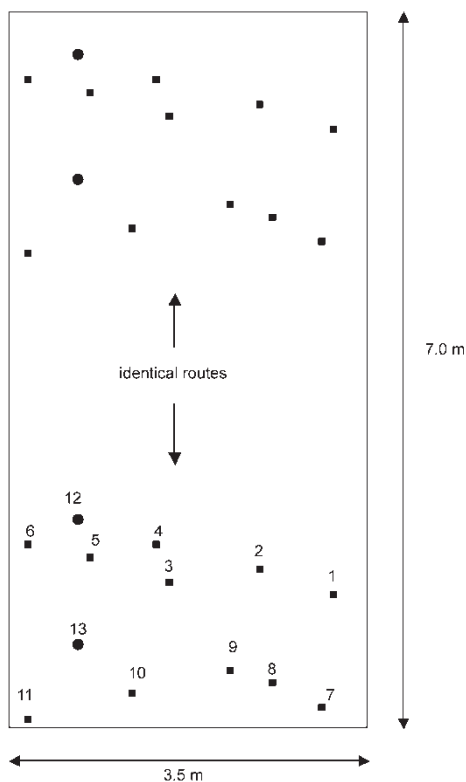


Figure 1. Front view of the climbing wall used in Experiments 1 and 2. The additional holds (Holds 12 and 13) used in Experiment 1 are indicated by •. The routes in the low and high condition are identical.

around a solid iron bar at the top of the climbing wall, and back to the ground. This end of the safety rope runs through the belay device on the belayer's harness. The belayer is the person who is managing the safety rope and preventing and protecting participants from falling down if they lose grip on the wall (Skinner & McMullen, 1993).

State anxiety was assessed by means of the "anxiety thermometer" validated by Houtman and Bakker (1989). The anxiety thermometer is a 10-cm continuous scale on which participants were asked to rate their anxiety feelings at a particular moment, ranging from 0 (*not anxious at all*, the left end) to 10 (*extremely anxious*, the right end). Participants had to place a cross on the 10-cm scale to indicate how they felt at a particular moment. The distance between the left end and cross (in cm) was used as a measure of the reported anxiety. Consequently, it is a quick way to measure state-anxiety in contrast to the often-used Competitive State Anxiety Inventory-2 (CSAI-2; Martens et al., 1990), which would be unsuitable for our purposes (see also Pijpers et al., 2003). For each measurement, a separate anxiety thermometer was used.

During climbing we recorded heart rate values every 5 seconds using a Sporttester (Polar Electro-3000). Afterwards, for every climb the mean heart rate was calculated.

Movements of the participants were recorded using two S-VHS camcorders at a sampling rate of 50 Hz. One camcorder was placed on the floor to get an overall view of the experimental set-up, and one (movable) was used to get a clear picture of the movements of hands and feet. Two experimenters

handled the camcorders. The videotapes were copied, and a Vertical Interval Time code (VIT code, a unique time code) was added using an Alpermann & Velte Time Code 30 generator. We used a video frame grabber and a digitizing program to determine the climbing times.

Procedure

Participants were tested individually and on one day. Participants were informed about the procedure of the experiment after which they signed a statement of informed consent. They completed the Dutch version of the STAI A-Trait scale (van der Ploeg et al., 1979) and filled out an anxiety thermometer (to familiarize them with the thermometer).

To make participants familiar with the climbing task a videotaped example of an experienced climber was shown. The climber demonstrated an efficient way to climb the traverse. A Sporttester was placed, and participants put on their climbing shoes and harness. They then practised the (low) traverse until they were able to climb the traverse two times back and forth properly and easily. Practice periods lasted from 5 to 10 minutes. After practising participants were allowed 15–20 minutes to fully recuperate.

Subsequently, participants were asked to take position on the wall: Participants placed their right hand on Hold 1 (see Figure 1), left hand on Hold 2, right foot on Hold 7, and left foot on Hold 8 ("starting position"). As soon as participants had taken position on the wall in the high condition the platform was quickly removed to prevent the risk of striking the platform. In the low condition, participants were instructed not to start climbing immediately, but to wait just as long as it would have taken to relocate the platform (less than 10 s). In both conditions participants started climbing at a sign from one of the experimenters.

In each condition, participants climbed two times. Starting at the right side of the wall participants climbed to the left side of the wall and then returned to the right side of the wall followed by a 5-minute break. After climbing in the high condition, participants stepped back on the platform. Next, participants climbed the other condition (high if they had started low, low if they had started high). Participants were then allowed a recuperation time of 20 minutes. Then the procedure of the first two climbs was repeated. Whether participants started low or high changed with every new participant. After each time participants had climbed, they had to rate their feelings of anxiety by means of the anxiety thermometer. Participants were asked to recall how anxious they had felt during climbing. The mean of the two anxiety scores (after the first and second climb in a condition) was used as an anxiety score for that condition. Participants were asked to climb as fast yet as safe as possible. It was emphasized that participants' first goal should be to complete the climbing task without falling. None of the participants fell during the experiment. In total, only six times did a participant slip from a foothold, without further consequences as the participants could recover easily from these slips. Three slips were made in the low-anxiety condition and three in the high-anxiety condition.

One of the experimenters served as bayer. In the low condition, the bayer acted as insurance that both conditions were similar for the climber. Participants were informed before beginning the climb in the low condition (mean height of the footholds, 0.4 m) that, despite the bayer, if they slipped they should break their fall themselves, as the safety procedure would not be effective so low above the ground.

Dependent variables

For each condition the following dependent variables were determined from the videotapes:

1. *Number of explorative movements*, defined as the number of times a hold was touched without it being used as support.

2. *Number of performatory movements*—that is, the number of movements made during climbing; a movement was defined as releasing a hold and making contact with another hold *and* using that hold as support.

3. *Use of additional holds*, defined as the number of times the additional holds (Holds 12 and 13; see Figure 1) were used during climbing.

Participants' movements were viewed by two independent raters for accurate determination of the dependent variables mentioned above. In all cases the raters agreed on the number of performatory movements, the number of explorative movements, and the number of times the additional holds were used.

4. *Climbing time* was also registered for each condition; it was defined as the sum of the time needed to climb the first and second climb in a condition. As soon as participants released one of the holds in the starting position, time started. When participants had returned to the starting position, the time was stopped.

Statistical analysis

The effect of height (low condition, high condition) was tested using several paired *t* tests (one-tailed) for the dependent variables mentioned above. Effect sizes of within factor (ES_w) were calculated to provide an estimation of the meaningfulness of a difference between two means (Mullineaux, Bartlett, & Bennett, 2001; Thomas & Nelson, 1996). An effect size of 0.2, 0.5, and greater than 0.8, represents small, moderate, and large differences, respectively (Cohen, 1988).

Results

State anxiety and heart rate

To determine whether the anxiety manipulation was successful we performed a paired *t* test on the anxiety thermometer data. Averaged over the two climbs participants reported significantly higher anxiety scores in the high condition than in the low condition, $t(7) = 3.46$, $p < .005$, $ES_w = 4.72$; the mean score on the anxiety thermometer in the high condition was 2.7 ($SD = 1.90$), and in the low condition 0.7 ($SD = 0.43$).

Averaged over two climbs per condition the mean heart rate differed significantly between conditions, $t(7) = 3.69$, $p < .05$, $ES_w = 1.45$, heart rate being higher in the high condition ($M = 157.3$, beats per minute, bpm, $SD = 14.63$) than in the low condition ($M = 143.3$ bpm, $SD = 9.66$). Both measures pointed to a successful manipulation of anxiety—that is, in the high condition participants were more anxious than in the low condition.

Behavioural variables

Table 1 shows the dependent variables for the low and the high condition. It appeared that climbing time increased significantly and by more than 50%, from 56.6 s in the low condition to 89.5 s in the high condition, $t(7) = 3.55$, $p < .05$, $ES_w = 0.96$. There were large individual differences in climbing time causing the large standard deviations. In the low condition climbing time ranged from 28 to 141 s, and in the high condition from 30 to 182 s. Note that the longer climbing time may partly explain the higher heart rates.

The number of explorative movements was significantly higher in the high condition than in the low condition, $t(7) = 1.99$, $p < .05$, $ES_w = 1.58$. The longer climbing time cannot be

TABLE 1
Climbing time^a, number of explorative movements, number of performatory movements, and use of additional holds for the conditions in Experiment 1

| Variable | Condition | | | |
|----------------------------------|-------------|-----------|--------------|-----------|
| | Low anxiety | | High anxiety | |
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Climbing time | 56.6 | 34.18 | 89.5 | 46.51 |
| Number of explorative movements | 2.5 | 2.45 | 6.4 | 7.40 |
| Number of performatory movements | 54.1 | 9.52 | 56.6 | 7.34 |
| Use of additional holds | 4.4 | 2.99 | 4.7 | 2.69 |

^aIn s.

explained by a significant increase in number of performatory movements since the number of performatory movements did not statistically differ between the low and high condition, $t(7) = 0.71$, $p = .25$. Furthermore, no significant difference was found between the low and high condition for use of additional holds, $t(7) = 0.27$, $p = .40$.

Discussion

In Experiment 1 we investigated manifestations of anxiety in movement behaviour via changes in number of exploratory movements, the number of performatory movements, and the use of additional holds. In addition, we calculated climbing time. The differences in climbing time in the low and high condition clearly revealed that participants' movement behaviour differed in both conditions. The increase in climbing time could be explained in part by an increase in the number of explorative movements, but not by an increase in the number of performatory movements or by the use of additional holds.

The substantially longer climbing time in the high-anxiety condition seems to be a robust finding as it replicates the results of our previous study (Pijpers et al., 2003). Together with the increase in explorative movements the longer climbing time showed that anxiety indeed changed participants' movement behaviour, which is in line with Masters' (1992) conscious processing hypothesis as well as with earlier results of Weinberg (1978; Weinberg & Hunt, 1976), Beuter and Duda (1985; Beuter et al., 1989), and Collins et al. (2001) who also found changes in movement behaviour associated with anxiety.

Anxiety had no significant effects on the total number of performatory movements made and on the number of times the extra holds were used. In retrospect, the number of holds on the wall probably did not leave enough room for many alternatives—that is, for an increase in the number of holds used. The number of holds constrained the number of possible movement solutions too much to find differences in the number of movements between conditions. It also appeared that in the low condition participants also made use of the additional holds, making *extra* use in the high condition hardly possible.

Note that, although statistically significant between conditions, the average anxiety scores were rather low. In both conditions the current scores were about half the scores of

Pijpers et al. (2003) who used the same climbing wall and about the same traverse. In the present experiment, participants had to climb twice in each condition. After the first climb in the high condition, participants stepped back on the platform and returned to the floor area. This procedure had a considerable diminishing impact on the average anxiety scores as participants experienced that nothing seriously happened to them. This is reflected in the anxiety thermometer scores: The first time participants had climbed in the high condition the average score on the anxiety thermometer was 3.5 ($SD = 2.46$), and the second time only 2.0 ($SD = 1.84$).

An issue to pursue is where the substantially longer climbing time in the high condition than in the low condition comes from as the increase in the number of explorative movements can only explain a small part of the longer climbing time. We addressed this issue in Experiment 2.

EXPERIMENT 2

In search for an explanation for the considerably longer climbing time in the high condition, in Experiment 2 we not only measured the number of exploratory and performatory movements, but also the temporal aspects of these movements—that is, how long participants grasped the holds in both conditions and how fast they moved from hold to hold. Temporal changes in movement patterns may point to an anxiety-induced renewed conscious control of movements as is to be expected from the conscious processing hypothesis (Masters, 1992; Mullen & Hardy, 2000). Recall that in this model anxiety is assumed to evoke an inward focus of attention on the execution of movements. This inward focus of attention and subsequent step-by-step control of movements is proposed to slow down the execution of sensorimotor skills (Beilock & Carr, 2001; Beilock et al., 2002a; Mullen & Hardy, 2000). As the cognitive processes involved will take more time than a more automated execution of the task, we expected a longer preparation of movements (i.e., longer contact times with the holds) as well as slower execution of the movements (i.e., slower movements from hold to hold) under high-anxiety than under low-anxiety conditions.

The design and procedure of Experiment 2 were largely similar to those of Experiment 1. However, two major methodological changes had to be made. First, to give us the opportunity to investigate the temporal aspects of movement execution, special technical adjustments to the holds were made (for more details, see method of Experiment 2). Second, in each condition participants had to climb the traverse two times back and forth without a break instead of with a break as was done in Experiment 1. We considered the break to be too harmful for our anxiety manipulation (see discussion of Experiment 1). Given the main purpose of Experiment 2, it was important that participants completed four traverses in the low as well as in the high condition to obtain sufficient data to make statistical analysis sensible.

Method

Participants

A total of 15 participants, 13 male and 2 female, mean age 20.7 years ($SD = 2.22$), volunteered to participate in the experiment. None of them had participated in Experiment 1. The participants, all college students, had no experience in climbing.

The mean trait anxiety score for the male participants was 35.8 ($SD = 10.98$), and for the (two) female participants 33.5 ($SD = 3.54$). The mean score of the male participants was comparable with the mean score for Dutch male college students ($M = 36.1$) obtained by van der Ploeg et al. (1980), $t(16) = 0.10$, *ns*, *t* test between a sample and a population mean (Thomas & Nelson, 1996). The two female participants were less trait anxious than Dutch female college students ($M = 37.7$, the 95% confidence interval ranges from 36.5 to 38.7, van der Ploeg et al., 1980). As in Experiment 1, the results indicated that the participants had no extraordinary predisposition to respond across many situations with high levels of state anxiety (e.g., Smith et al., 1998).

Experimental set-up

Participants climbed on the same climbing wall as that in Experiment 1 in a low and high condition. Again, two identical, horizontal routes (traverses) were mounted on the wall, each consisting of five footholds and six handholds (see Figure 1). We removed the additional holds (Holds 12 and 13) used in Experiment 1, as including them did not provide additional information with respect to participants' movement behaviour. Due to the equipment needed to register the contact time between a hand and a hold and between a foot and a hold (see below) it was necessary to slightly change the positions of the holds. The mean height of the five footholds of the low traverse was 0.3 m (*low* condition); the mean height of the five footholds of the high traverse was 4.9 m (*high* condition). To enable participants to begin the climb on the wall in the same physical condition as that in the low traverse, again the movable platform was used. The platform was positioned at a distance from the wall calculated as 1.5 times the length from a participant's arm. Tests prior to the experiment established that if participants fell while climbing the high traverse, this was a distance at which they were at no risk of striking the platform. Therefore, it was not necessary to replace the platform, and participants could start climbing when they were ready. Participants in the high condition were assisted in crossing over this platform prior to climbing, and they were held by one of the experimenters until they indicated that they were ready to start. In the low condition this situation was simulated by asking participants to begin from behind a line marked clearly on the floor. The line was positioned at the same distance from the wall as was the platform in the high condition. In the low condition it was not considered necessary to support the participants. Instead, an experimenter stood behind them and indicated that they should begin when they were ready.

Each hold on the climbing wall was equipped with on/off switches (see Figure 2). Vertical pressure from the climber's foot activated the switch (threshold 2–5 N). The handholds could be activated in the vertical as well as in the horizontal direction. Pressure from the participant's foot or hand activated a signal to the personal computer. Releasing pressure from the hold resulted in deactivating the switch. This equipment made it possible to determine the time of hand-hold contact and the time of foot-hold contact and, hence, the time participants moved from one hold to the other, as well as the total climbing time, with an accuracy of 1–5 ms (see also later under Dependent Variables).

As in Experiment 1 participants wore well-fitting climbing shoes and an integral harness connected to a climbing rope. The same security procedure as that in Experiment 1 was used. The wall was screened from public view by black plastic sheeting. At the top, the sheeting was connected to the movable platform and extended outward and downward to the floor in the shape of a tent, approximately 3 m from the wall. All climbs were videotaped using an S-VHS camcorder (sampling rate of 50 Hz). In the low condition, the camcorder was in a fixed position behind and above the climber. The fixed position monitored all the hand- and footholds. Participants' hand and foot movements were clearly visible. In the high condition, an experimenter standing on the elevated platform held the camcorder and moved with participants to record participants' movements. State and trait anxiety and heart rate were measured in the same way as in Experiment 1.

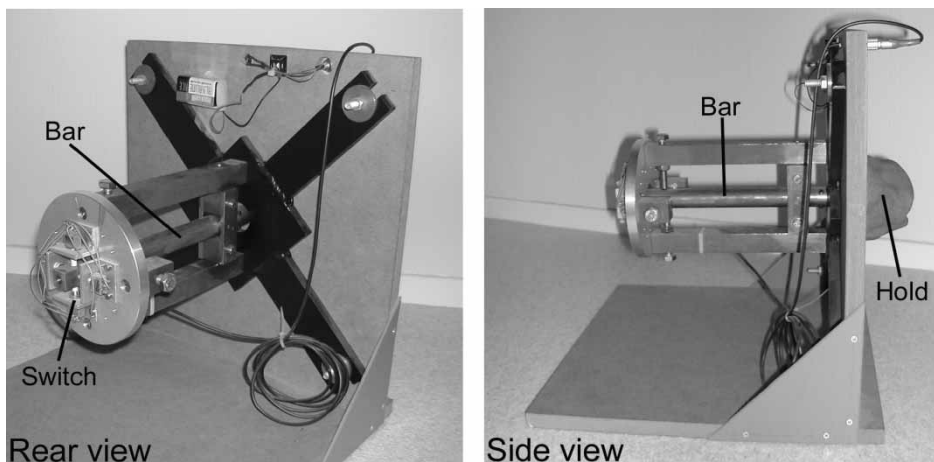


Figure 2. Model of (hand)hold-time registration mechanism. All holds on the climbing wall were equipped with such a time registration mechanism. The hold was connected with a bar that went through the climbing wall (see right panel). Pressure from participant's hand or foot activated one of the switches, causing a signal to the computer. The handholds could be activated in the vertical as well as in the horizontal direction (see left panel), the footholds only in the vertical direction. Releasing pressure from the hold resulted in deactivating the switch.

Task execution

As in Experiment 1 participants were asked to climb as fast yet as safe as possible but it was stressed that the participant's first goal was to complete the climbing task without falling. They were told that a fall would immediately end the experiment. During the experiment, none of the participants fell. In case of a fall, the trial would neither be completed nor re-run, but the participant would be excluded from the experiment and experimental analyses. When participants make a fall, they experience that they run no risk. Consequently, climbing the high traverse once more would be experienced as much less anxiety provoking. One participant almost fell during the fourth traverse in the high condition but could recover without support from the safety rope and complete the task. Two participants once slipped off a foothold with one foot, both in the low condition.

Procedure

Before the day of the experiment, all participants completed the STAI A-Trait inventory in the presence of one of the experimenters. Participants were tested individually on the next day. Their total involvement in the experiment was approximately two hours. The entire procedure was explained to each participant. Participants were then asked to read and sign a statement of informed consent. Participants were not informed that climbing time was one of the variables being measured.

After changing into sport clothing, each participant was fitted with climbing shoes and given the opportunity to practise on the wall. As debriefing sessions in Experiment 1 made clear that the videotaped climbing example was not very helpful in task execution we only gave verbal instructions in Experiment 2. When necessary general, nontechnical instructions were given to participants, for example "use your legs" to prevent them becoming too tired and not being able to complete the climbing task. No specific instructions were given on how to climb faster or to execute movements. Practice periods lasted from 5 to 10 minutes and stopped when participants were able to successfully complete the traverse on the wall four times without a pause (see also below). This opportunity to practise prior to the experiment

was given to all participants. It allowed the experimenters to be confident that a participant's failure to complete the task in either condition would not be due to lack of experience with the task.

Following the practice period, the Sporttester was placed. The watch indicating the recorded number of beats was attached to the belt behind the participant's back to prevent it from being read by the participant. Participants were then taken outside the screened off area and allowed 30 minutes to fully recuperate.

Approximately 10 minutes before each condition (high and low conditions were counterbalanced), participants were brought back to the wall and seated, either on the platform or the floor, depending on condition. Two minutes before the climb participants were asked to indicate how anxious they were at that moment by completing the anxiety thermometer (to familiarize them with the thermometer). Then, participants were led to the wall and connected to the rope. The Sporttester was switched on, and participants were instructed to begin when ready. The computer began recording when participants had both hands and both feet on the wall (right hand on Hold 1, left hand on Hold 2, right foot on Hold 7, and left foot on Hold 8, see Figure 1). This was the starting position. Time was stopped when participants had resumed the starting position after participants had climbed the traverse four times—that is, starting at the right side of the wall the participants climbed to the left side (first traverse), then returned to the right side (second traverse), again to the left side (third traverse), and again back to the right side of the wall (fourth traverse).

Immediately after each condition, participants were asked to recall how anxious they had felt *during* climbing and to record this on the anxiety thermometer scale. This was used as anxiety score for that condition.

Participants were allowed a recuperation period of between 30 and 40 minutes before starting the second condition. During this period, they were brought outside the screened area and offered refreshments. They were not encouraged to talk about the climb. If participants mentioned the experience, one of the experimenters would respond in a general way to the remark and then endeavour to change the subject. No information about the recordings that were taken was given to the participants. If they asked questions, they were told that on completion of the experiment all questions would be fully answered. The second condition was executed in a similar fashion as the first, but now participants climbed in the other condition (low if they had started high, high if they had started low).

Dependent variables

The equipment used in this experiment made it possible to determine with great accuracy a number of dependent variables. To visualize the movement patterns of each participant, all the participant's climbing movements were coded on a sheet (for an example, see Figure 3). This made it easier to determine the number of movements, when a particular movement started and ended, how long a hold was grasped, and so on.

First, to make a direct comparison with the results of Experiment 1 possible, the dependent variables climbing time (and two dependent variables related to climbing time, namely traverse time and rest between traverses), number of explorative movements, and number performatory of movements were determined.

1. *Climbing time* was defined as the time needed to climb the traverse four times. Time started as soon as participants had left the starting position and stopped as soon as participants had resumed the starting position after climbing the traverse four times.

2. *Traverse time* was defined as the time needed to climb one traverse—that is, for the first and third traverse the period between releasing one of Holds 1, 2, 7, or 8 (starting position) and making contact with Hold 6 (left hand), Hold 5 (right hand), Hold 11 (left foot), and Hold 10 (right

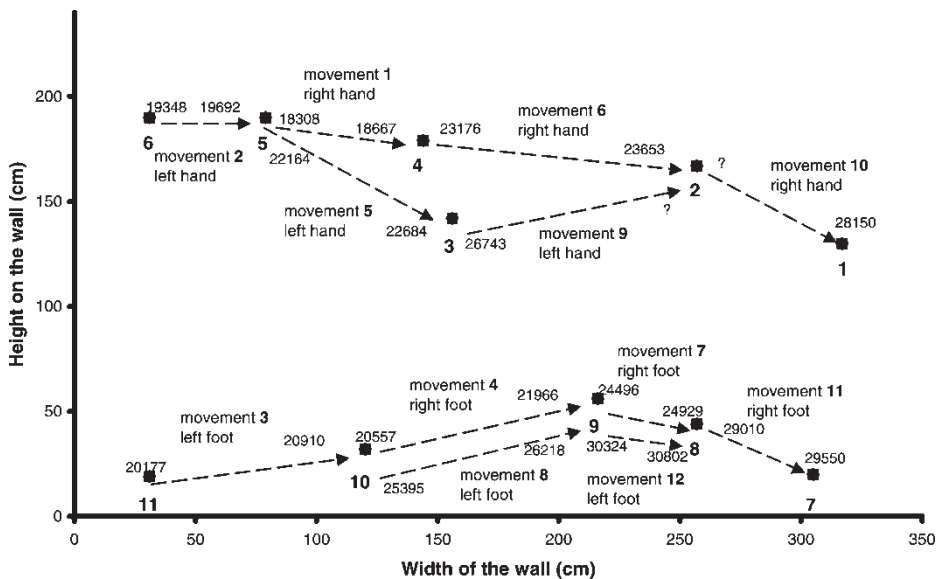


Figure 3. Typical example of how the route was climbed. Shown here is the second traverse (low condition). The black squares indicate the positions of the holds. The times the movement started and stopped are indicated above the arrow (left: time the movement started, in ms; right: time the movement ended, in ms). The question mark at the end of Movement 9 (left hand) indicates that it was not possible to determine the time Movement 9 ended because Hold 2 was already activated by the right hand (Movement 6). Likewise, it was not possible to determine the start of Movement 10 (also indicated by a question mark) because the left hand still activated Hold 2.

foot; end-position; see Figure 1). The time to climb the second and fourth traverse was defined as the period between releasing one of Holds 5, 6, 10, or 11 and returning to the starting position at the right side of the wall.

3. *Rest between traverses* was defined as the duration of the breaks between traverses: thus, from reaching the starting position or end position until initiation of the first movement away from that position.

4. *Number of explorative movements* and *number of performatory movements* (see Experiment 1 for a definition of this variable). The time constraint for an exploratory movement was that it had to last at least 500 ms—that is, the hold from where it started had to be released minimally 500 ms before the hand or foot returned to this hold again (with or without touching another hold). Otherwise it was not considered an exploratory movement.

Second, we calculated the total contact times with the holds (*total contact time*) as well as those for feet and hands separately (*total contact time feet* and *total contact time hands*, respectively). In the first instance, this was done irrespective of movement pattern (i.e., which holds were used and in which sequence), which could, of course, have been different in the high and low conditions. *Total contact time* was defined as the sum of all contact times of all holds for each participant (thus, *total contact time feet* + *total contact time hands*).

Third, we determined the average movement times from hold to hold (*average movement time*) both for the feet (*average movement time feet*) and for the hands (*average movement time hands*); again this was done irrespective of movement pattern.

Fourth, we analysed contact time and movement time of a selected number of (sequences of) movements that were similar in the low and high condition, hereby correcting for possible differences in movement patterns that may have played a role in the other analyses.

Statistical analysis

As in Experiment 1 several paired t tests were executed. When necessary, two-factor repeated measures analyses of variance ANOVAs were used. Eta squared (η^2) assessed the explained variance in the ANOVA models. Pair-wise comparisons using t tests were made using the Bonferroni correction procedure (Kinnear & Gray, 2000) to identify specific mean differences when a significant main effect was found. The p values that are reported on the basis of this Bonferroni method are scaled to the .05 alpha level, so that, as usual, p values smaller than .05 indicate a significant effect.

Results

Anxiety scores and heart rate

Participants reported significantly higher anxiety scores in the high condition ($M = 6.5$, $SD = 2.38$) than in the low condition ($M = 3.4$, $SD = 1.96$), $t(14) = 5.24$, $p < .001$, $ES_w = 1.60$. The mean heart rate appeared to be higher in the high condition ($M = 145.9$ bpm, $SD = 19.30$) than in the low condition ($M = 126.3$ bpm, $SD = 18.37$), $t(13) = 4.01$, $p < .001$, $ES_w = 1.07$. (Due to a technical problem one of the heart rate measurements was missing.)

The results indicated that the anxiety manipulation was again successful: In the high condition state anxiety was higher than in the low condition.

Climbing time, traverse time, rest between traverses, number of explorative movements, and number of performatory movements

An overview of the results concerning climbing time, traverse time, rest between traverses, number of explorative movements, and number of performatory movements (hand and foot movements) is presented in Table 2. As in Experiment 1 and our previous study (Pijpers et al., 2003), the climbing time in the high condition was significantly longer (about 22%) than that in the low condition, $t(14) = 4.59$, $p < .001$, $ES_w = 1.17$. A 2 (height: low condition, high condition) \times 4 (traverse: Traverse 1–4) repeated measures ANOVA on the traverse time data also revealed a significant main effect of height, $F(1, 14) = 26.00$, $p < .001$, $\eta^2 = .65$, confirming that the average traverse time was longer in the high condition than in the low condition. The main effect of traverse did not reach the 5%, but the 10%, significance level, $F(3, 43) = 2.39$, $p < .10$, $\eta^2 = .15$. Participants tended to climb faster in the fourth traverse ($M = 14.77$ s, $SD = 2.907$) than in the first traverse, ($M = 16.43$ s, $SD = 3.759$), second traverse ($M = 16.48$ s, $SD = 2.820$), and third traverse ($M = 16.54$ s, $SD = 2.360$). The Bonferroni t tests for making comparisons among the means of the traverse time data showed that participants climbed the fourth traverse significantly faster than the second traverse ($p < .05$). The interaction between height and traverse was not statistically significant, $F(3, 42) = 0.74$, $p = .54$.

The analysis of the variable rest between traverses produced no significant effect, $t(14) = 0.44$, $p = .33$, hence the breaks between traverses did not contribute to the longer climbing times in the high condition. As in Experiment 1 the number of explorative

TABLE 2
Climbing time^a, traverse time^a, rest between traverses^a, number of
explorative movements, number of performatory movements,
number of foot movements, and number of hand movements for
the conditions in Experiment 2

| Variable | Condition | | | |
|----------------------------------|-------------|--------|--------------|--------|
| | Low anxiety | | High anxiety | |
| | M | SD | M | SD |
| Climbing time | 62.13 | 11.987 | 76.09 | 11.032 |
| Traverse time | | | | |
| Traverse 1 | 15.11 | 3.603 | 17.75 | 5.100 |
| Traverse 2 | 14.16 | 3.649 | 18.81 | 3.541 |
| Traverse 3 | 14.77 | 3.282 | 18.32 | 3.428 |
| Traverse 4 | 13.30 | 3.530 | 16.23 | 3.320 |
| Rest between traverses | 4.81 | 1.374 | 4.98 | 2.017 |
| Number of explorative movements | 1.2 | 1.21 | 2.0 | 1.60 |
| Number of performatory movements | 49.6 | 6.14 | 50.3 | 4.11 |
| Foot movements | 21.9 | 3.16 | 23.0 | 2.36 |
| Hand movements | 27.7 | 3.58 | 27.3 | 2.94 |

^aIn s.

movements was significantly higher in the high condition than in the low condition, $t(14) = 1.87$, $p < .05$, $ES_w = 0.66$. Also, in line with the results of Experiment 1, the number of performatory movements was not significantly different in the low and high condition, $t(14) = 0.86$, $p = .20$. Investigating foot and hand movements separately, it appeared that more foot movements were made in the high condition than in the low condition, though the difference was not significant, $t(14) = 1.75$, $p < .10$, $ES_w = 0.36$. The number of hand movements was not significantly different between conditions, $t(14) = 0.92$, $p = .19$.

To summarize, again climbing time was considerably longer in the high condition than in the low condition, which can partly be explained by more explorative movements and perhaps more foot movements. Participants did not take more rest between traverses, and the total number of performatory movements was not significantly different in both conditions.

Contact times and movement times (irrespective of movement pattern)

Table 3 presents the results of the time hands and feet made contact with the holds—that is, total contact time, total contact time feet, and total contact time hands irrespective of movement pattern (i.e., which holds were used and in which sequence). The total contact time in the high condition was significantly longer than that in the low condition, $t(14) = 5.40$, $p < .001$, $ES_w = 1.23$. In addition, total contact time feet, as well as total contact time hands, was significantly longer in the high condition than in the low condition, $t(14) = 5.85$, $p < .001$,

TABLE 3
Total contact times^a, and average movement times^b for the
conditions in Experiment 2

| Variable | Condition | | | |
|-----------------------------|-------------|-----------|--------------|-----------|
| | Low anxiety | | High anxiety | |
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Total contact time | 187 | 41.7 | 239 | 35.8 |
| Total contact time feet | 93 | 25.2 | 119 | 18.7 |
| Total contact time hands | 95 | 22.0 | 119 | 17.5 |
| Average movement time | 739 | 95.4 | 845 | 130.8 |
| Average movement time feet | 895 | 156.6 | 1,023 | 223.2 |
| Average movement time hands | 543 | 74.01 | 599 | 122.4 |

Note: Movement patterns are not taken into account

^aIn s.

^bIn ms.

$ES_w = 1.33$, and $t(14) = 4.86$, $p < .001$, $ES_w = 1.13$, respectively. Thus, participants made contact with the holds longer, both with their hands and with their feet when they were anxious.

Overall, participants also moved slower from hold to hold in the high condition than in the low condition.³ The average movement time from hold to hold in the high condition was 845 ms, which was significantly longer than the average movement time of 739 ms in the low condition, $t(10) = 2.89$, $p < .05$, $ES_w = 1.11$. Again, these slower movements occurred both with feet and hands. The average movement time for feet was significantly longer in the high condition than in the low condition, $t(10) = 2.27$, $p < .05$, $ES_w = 0.82$. The difference in average movement time for hands was not significant between high and low conditions, $t(10) = 1.80$, $p < .10$, $ES_w = 0.76$.

To reiterate, in the high condition participants grasped the holds longer and moved slower from hold to hold than in the low condition. Both longer contact times and slower movements contributed to the longer climbing times in the high-anxiety condition.

Average movement times (for similar movements)

In principle, the above-mentioned differences could have been due to differences in movement pattern that were not taken into account. Different movement patterns may lead to different contact and movement times. Although averaged over all participants the number of performatory movements made did not significantly differ between the two conditions, there were large individual differences in climbing the low and high routes. It might well be that the total contact times and the average movement times were the result of the use of different holds and different movement patterns rather than longer holding and slower movements. To correct movement times with respect to these possible movement pattern differences,

³Movement time cannot be calculated if two feet or two hands touched the same hold at the same time. If this was the case switches remained activated when one of the hands or feet moved away, making it impossible to discriminate different movements. A total of 4 participants were not included in the movement time analyses as they touched a hold twice at the same time so often that not enough data were available to calculate average movement times.

we selected parts of traverses that were climbed in a similar way in both conditions.⁴ This allowed us to calculate the average movement time for feet and the average movement time for hands. Eventually, 196 pairs of similar movements in the low and high condition (107 foot movement pairs and 89 hand movement pairs) could be analysed (about 26% of the total number of movements, cf. Table 2).

It appeared that participants' foot movements from hold to hold were significantly slower in the high condition ($M = 964$ ms, $SD = 485.9$) than were similar feet movements in the low condition ($M = 847$ ms, $SD = 442.3$), $t(106) = 2.55$, $p < .05$, $ES_w = 0.26$. In addition, it appeared that the average movement time for hands was significantly longer in the high condition ($M = 596$ ms, $SD = 297.0$) than in the low condition ($M = 529$ ms, $SD = 194.6$), $t(88) = 2.42$, $p < .05$, $ES_w = 0.34$. Thus, also when the movements were similar in both conditions, movement time of foot as well as hand movements appeared to be significantly longer in the high-anxiety condition than in the low-anxiety condition.

Discussion

The purpose of Experiment 2 was to provide more insight into how motor performance changes as a function of anxiety. We focused specifically on the temporal aspects of movements. The results showed that anxiety was successfully induced. Self-report scores indicated that participants felt more anxious in the high condition than in the low condition. Compared to Experiment 1 participants reported substantially higher anxiety scores, indicating that our change in the procedure between experiments (from climbing twice in each condition to climbing once in each condition) was successful. Again, heart rate appeared to be higher high on the wall than low on the wall, which might self-evidently also be a reflection of the longer climbing times.

As in Experiment 1, the higher self-report scores and the higher mean heart rate went hand in hand with longer climbing times and more exploratory movements. In addition, it appeared that participants also grasped holds longer, and on the whole they moved slower from hold to hold. These findings can largely explain the longer climbing times found under anxiety-provoking conditions and are in agreement with Masters' (1992) conscious processing hypothesis. In the General Discussion we elaborate on this issue.

GENERAL DISCUSSION

The main aim of the present study was to examine anxiety-related changes in participants' movement behaviour in order to gain insight into the mechanisms through which anxiety may affect performance in various settings such as sports (e.g., serving for match point in

⁴We also executed analyses with 28 whole traverses that were climbed high and low using similar movement patterns. As the configuration of the handholds did not enable participants to climb the traverse without using one of the handholds with two hands at the same time (making it often impossible to distinguish different hand movements), we had to restrict these analyses to the movements of the feet. Results were similar to the results of the analyses that did not take into account movement pattern. That is, in the high condition participants stood longer on the holds, and they moved significantly slower from hold to hold than in the low condition. As a result climbing time was significantly longer in the high condition than in the low condition.

tennis), dance (e.g., auditioning for ballet school or performing), musical performance (e.g., making one's first appearance in a renowned orchestra), police work (e.g., shooting in the line of duty), work of fire fighters (e.g., rescuing people from the fire), and armed forces (e.g., flying a jet plane in war time). We set out from Masters' (1992) conscious processing hypothesis that under pressure one may resort to renewed conscious control of movements that would normally be executed automatically. In keeping with this hypothesis we expected that the changes in movement control would be reflected in movement behaviour as was also already found by Pijpers et al. (2003)—that is, longer climbing times in the high-anxiety than in the low-anxiety condition. In search for an explanation for these longer climbing times, we extended the investigation of the effects of anxiety on movement behaviour to (number of) limb movements and their temporal patterning.

Although the findings are in line with the hypotheses (see below), three alternative explanations need to be considered first. Next to differences in anxiety there are three other factors that may vary across conditions: the fact that participants practised low only, the difference in peripheral vision between conditions, and possible differences in task interpretation between conditions.

Practising low only

To guarantee a difference in anxiety and to prevent participants from habituating to the high-anxiety condition we could only have participants practise the low traverse. In principle, this could have given participants an advantage in this condition, leading to more efficient behaviour low on the wall and explaining the differences between conditions. However, we consider this option unlikely on the basis of two accounts. First, considering the principles of transfer of learning (e.g., Adams, 1987; Magill, 1998; Newell, 1981, 1985), there is no reason to believe that there was no positive transfer of practising the task low on the wall to performing the task high on the wall. The tasks in the low and high condition show large resemblances, making positive transfer very likely (see Magill, 1998).

Second, to find out whether the results could have followed from practising low only, we compared (for Experiment 2) climbing time of the last two traverses in the high condition with those of the first two traverses in the low condition. Thus, we compared two traverses in the high condition that were executed after the first two high traverses (which could be considered as high "practice"), with the first two low traverses that were executed after the low-practice trials. This was done irrespective of the order of conditions (high-low, or low-high). There was a significant effect of condition, with the high climbing times being longer than the low climbing times, $t(14) = 3.90$, $p < .001$, $ES_w = 0.79$, even though there was a general tendency that the fourth traverse was climbed fastest (see results of Experiment 2). As a final test we compared, for those who climbed low first and then high, climbing time of the first two low traverses (preceded by the low practice trials only) with the last two high traverses (preceded by the low practice trials, the low condition—four traverses—and the first two high traverses). One would expect that on these last two traverses at least a similar advantage of experience with the task would have been present. Again, climbing times were significantly longer in the high than in the low condition, $t(7) = 2.03$, $p < .05$, $ES_w = 0.64$. Thus, even after some high practice the difference in movement execution between conditions remains, making it unlikely that practising the low traverse only

was responsible for the more efficient performance in the low condition than in the high condition.

Difference in peripheral vision

There is also a difference in the peripheral field of view in the low and high conditions, which might be responsible for the differences found in movement behaviour. But it is important to realize that this is part and parcel of our anxiety manipulation. The evoked anxiety in the high condition may partly follow from the modified peripheral vision. It is unclear how the changed peripheral vision itself would change task execution, especially since participants moved very close to the wall. As it is unlikely that peripheral vision outside the traverse contributes to the control of the climbing movements, it is also unlikely that the change in peripheral vision itself would explain the changes in movement behaviour.

Task interpretation

Another option is that participants may have approached the two traverses, high and low, differently, perhaps leading to different strategies in climbing and consequently to differences in behaviour. To exclude this possibility, the 11 participants of whom a complete dataset was available (see also Footnote 3) were divided in two “anxiety” groups on the basis of their anxiety thermometer scores when climbing the *high* traverse: a “lower anxious” group ($M = 5.0$, $SD = 1.53$, $n = 5$) and a “higher anxious” group ($M = 7.7$, $SD = 0.86$, $n = 6$), $t(9) = 3.58$, $p < .05$. If the high–low differences are attributable to anxiety, movement behaviour of the lower anxious group should be different from the movement behaviour of the higher anxious group when climbing high. If, however, high–low differences are due to strategic differences, no differences in movement behaviour are to be expected as all participants in this comparison received the same instruction and climbed in the same environment—that is, high on the wall. We did find significant differences between these two groups on most of the relevant variables: climbing time, traverse time, rest between traverses, number of performatory hand movements, total contact time, total contact time feet, and total contact time hand, $t_s > 1.90$, $p_s < .05$. It is difficult to interpret these differences as following from different task interpretations as the task and task environment were now identical for all participants in this comparison.

The factor that remains as explanation for the differences found in movement behaviour is anxiety. It appeared that the longer climbing time in the high condition could be explained for a small part by an increase in the number of explorative movements, an indication of the uncertain (hesitant) movement behaviour that also characterizes the early learner. In Experiment 2 we also found that in the high-anxiety condition participants not only grasped the holds longer, but they also made slower movements from hold to hold, again changes in movement behaviour that may also be found when there is more conscious processing, due to an inward focus of attention to the step-by-step control of skill execution. Thus, when participants were anxious their movement behaviour resembled the movement behaviour that can also be found in earlier stages of learning (see also, Baumeister, 1984; Beilock et al., 2002a; Beilock et al., 2002b; Hardy et al., 1996; Liao & Masters, 2002; Mullen & Hardy, 2000; Pijpers et al., 2003). This generally confirms Masters’ (1992) conscious processing

hypothesis. All in all, together with other findings in the recent literature (e.g., Beilock & Carr, 2001; Lewis & Linder, 1997; Mullen & Hardy, 2000) the (indirect) empirical support for the conscious processing hypothesis seems quite substantial.

The conscious processing hypothesis seems fit to explain the well-known and dreaded phenomenon of choking under pressure (Baumeister, 1984), especially when one is executing a concrete task—for example, in sports when one takes a decisive penalty shot in football or putt in golf under high situational demands. Performers who are about to execute that kind of task venture to reinvest in controlled processing: They are likely to think about what they are doing and what they have to do. Hence, despite individual striving, performance decreases. Thus, the conscious processing hypothesis seems to provide a plausible explanation for the relation between anxiety and performance especially when it concerns the execution of concrete tasks that are clearly “defined from start to end” and that are self-paced, such as golf putting (Beilock & Carr, 2001; Beilock et al., 2002a; Hardy et al., 1996; Mullen & Hardy, 2000). Eysenck and Calvo’s (1992) processing efficiency theory (see Footnote 1) seems to be more concerned with effects of anxiety on performance *throughout* an extended pattern of activities (e.g., an entire match or season) when performers often appear to maintain performance through additional effort.

Whether changes in movement behaviour actually result in a deterioration of performance may also (next to the task itself) depend on task instruction. It may be the case that using the same task but providing different instructions may lead to support for either the processing efficiency theory or the conscious processing hypothesis. For instance, when participants were forced to climb traverses in a fixed preset time of 20 s (Pijpers et al., 2003, Exp. 1) it was found that anxiety went hand in hand with a maintenance of performance as well as with more muscle tension and a higher blood lactate concentration as would be predicted by Eysenck and Calvo’s (1992) processing efficiency theory. These results suggest that with additional efforts participants were able to climb the high traverse in the same time as they did the low traverse.

Thus, task domain (concrete task or continued activity), task instruction, and hence intention (does one strive for a personal best or just to complete the task without falling), seem to be important mediators of the anxiety–performance relationship. To account for the wide range of possibilities of the influence of anxiety on different aspects of performance in the fields of sports, dance, armed forces, and so on, it seems that the “best explanation currently available may be a combination of processing efficiency theory and the conscious processing hypothesis” (Edwards, Kingston, Hardy, & Gould, 2002, p. 14). Both process-oriented accounts of the anxiety–performance relationship may serve as a guide for future research to gain a better understanding of the multifaceted interaction between anxiety and performance.

As for the practical implications a crucial question is how choking under pressure can be prevented. When a skilled performer is in a high-achievement setting it seems important to prevent the inward focus of attention and the accompanying attempts towards conscious step-by-step control of movement execution. While this is easier said than done, this may be feasible by applying sport psychological training techniques (Le Scanff & Taugis, 2002; Morris, 1997; Wann, 1997). In the long run it may be better for teachers and instructors to organize the learning environment of perceptual-motor skills in such a way that eventually performance is less susceptible to the phenomenon of choking under pressure. This idea is

supported by research into the paradigm of implicit versus explicit learning of perceptual-motor tasks (Hardy et al., 1996; Masters, 1992, 2000; Maxwell, Masters, & Eves, 2000; Wulf & Weigelt, 1997), which has demonstrated that preventing the development of explicit knowledge about task execution during the learning process may make performance less vulnerable to choking. This suggestion is corroborated by the studies into analogy learning in which only one explicit rule, rather than a large number of rules, guides the learning of the skill (Liao & Masters, 2001; Masters, 2000). Second, instructions that direct the learners' attention to the effects of their movements on the environment (external focus) and, thus, away from movement execution, appear to be more effective than instructions that direct performers' attention to their own movements and how to execute them (internal focus; Wulf, Höß, & Prinz, 1998; Wulf, McNevin, Fuchs, Ritter, & Toole, 2000; Wulf & Weigelt, 1997; for an overview, see Wulf & Prinz, 2001). Finally, next to the different ways of learning a skill (implicit vs. explicit, internal vs. external attention) the conditions in which learning took place appear to be crucial as well. Several studies show that when perceptual-motor skills are learned under conditions inducing self-awareness (Lewis & Linder, 1997), or self-consciousness (Beilock & Carr, 2001), choking is inoculated. Thus, getting used to the pressure may prevent choking, which provides an argument for simulating pressure-filled *learning* and *training* environments, which can easily be accomplished with the presence of a camera or (expert) spectators, placing (small) bets on performance, or practice contests, as long as the stakes and, hence, self-consciousness and pressure, are increased.

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